Karlsruhe Institute of Technology

Humanoids 2011
Workshop “New Bodies for Cognitive Humanoids”
Bled, Slovenia, 26. October 2011

Towards High Performance 24/7 Humanoids

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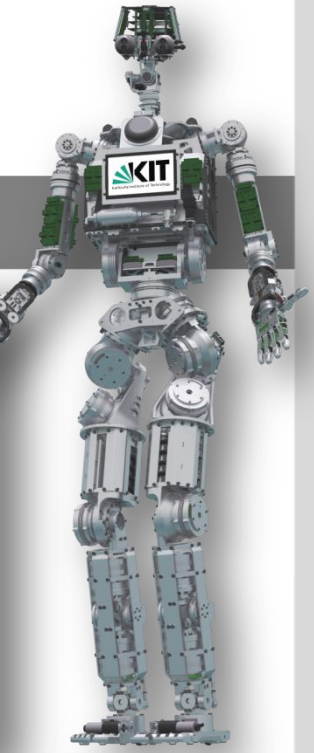


http://his.anthropomatik.kit.edu

http://his.anthropomatik.kit.edu/english/65.php

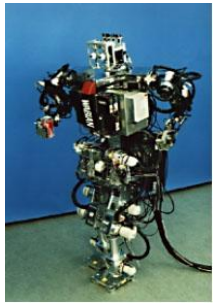
Building Humanoids

Building Humanoids = Building Human-Centered Technologies



- Assistants/companions for people in different ages, situations, activities and environments in order to improve the quality of life
- Key technologies for future robotic systems
- Experimental platforms to study theories about humans from other disciplines

Humanoid robot examples

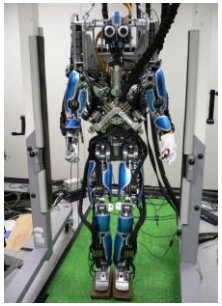


WABIAN

P2

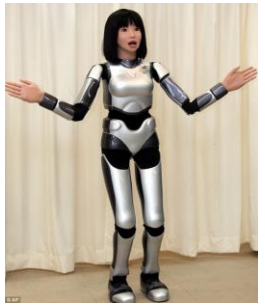
KOBIAN

DB

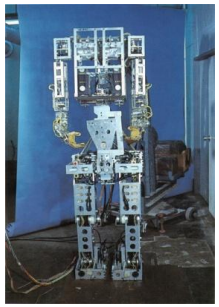


CB

iCub



HRP-4C



WABOT-1

ASIMO

HRP-2

ARMAR

Partner Robot

Hubo

Robonaut

Major goals in humanoid research

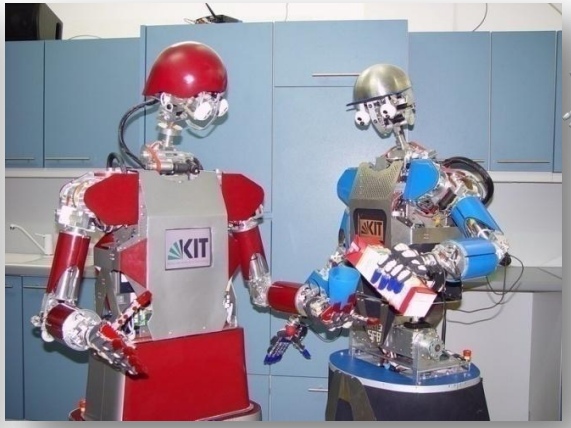
- Advanced human-like mechatronics systems
- Tools to study humans

Humanoid Robots @ KIT

ARMAR, 2000

ARMAR-II, 2002

ARMAR-IIIa, 2006



ARMAR-IIIb, 2008

ARMAR-IV, 2011

- Collaborative Research Center 588: Humanoid Robots - Learning and Cooperating Multimodal Robots (SFB 588)
  - Funded by the German Research Foundation (DFG: Deutsche Forschungsgemeinschaft)
  - 2001 – 2012
  - http://www.sfb588.uni-karlsruhe.de/

Three key questions

- Grasping and manipulation in human-centered and open-ended environments
- Learning through observation of humans and imitation of human actions
- Interaction and natural communication

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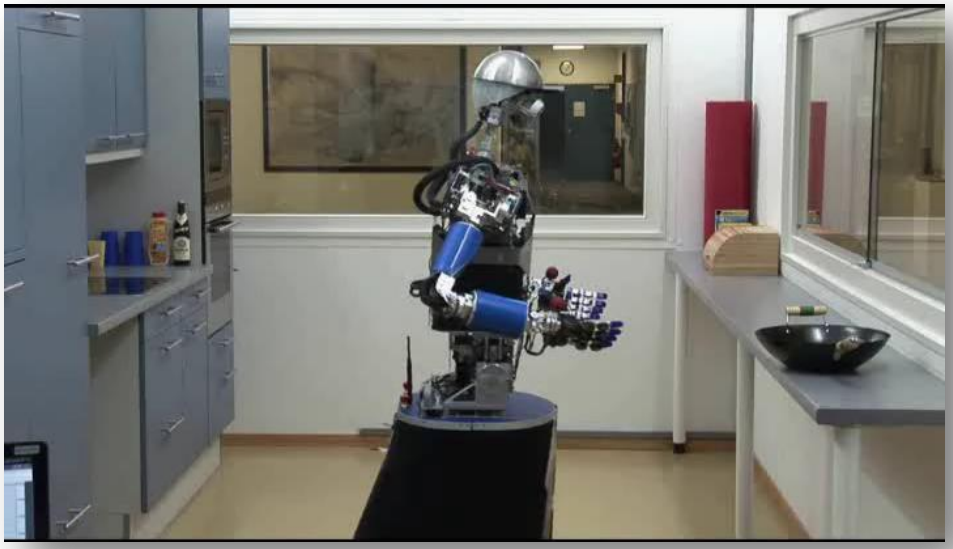
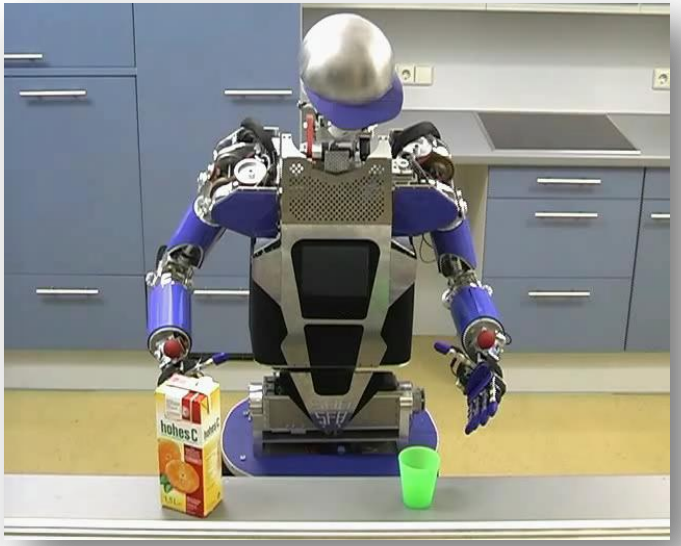
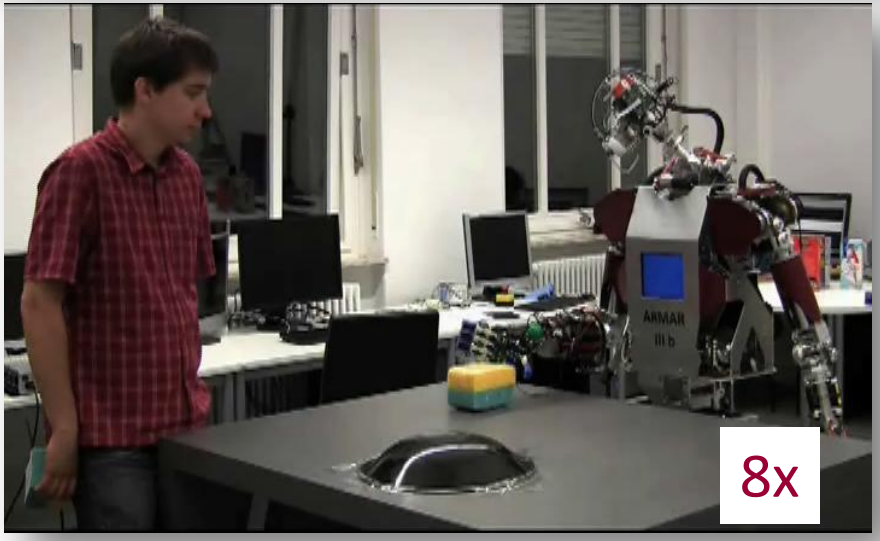
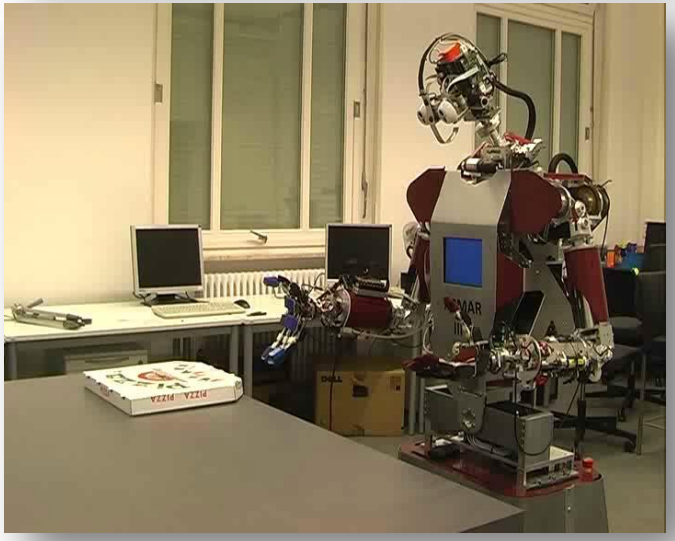
ARMAR in the Robo-KITchen

The ARMARs in the Robo-KITchen

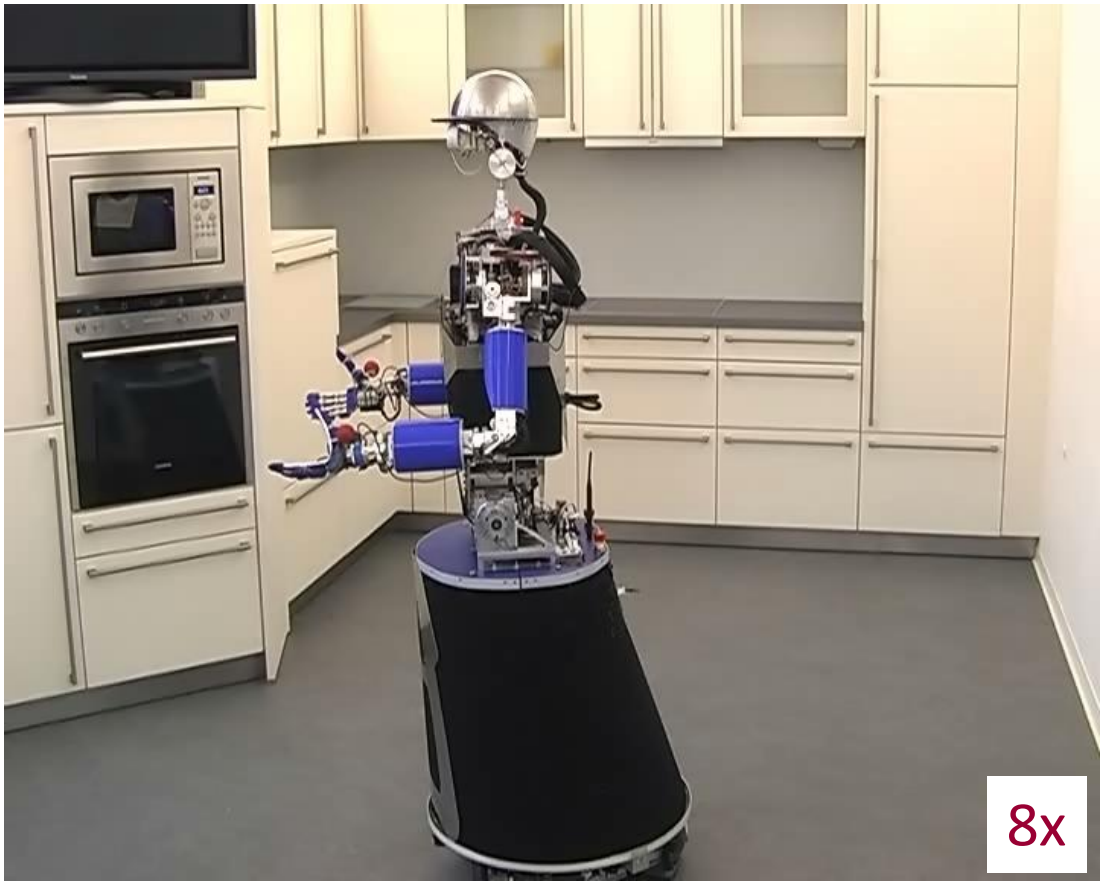






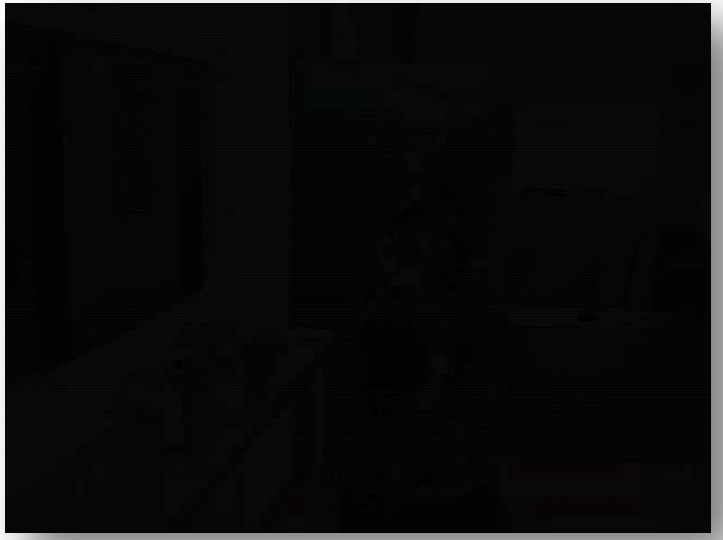


ARMAR in the Robo-KITchen



Current systems are limited in their capabilities

- Speed
  - Open the dishwasher
    - ARMAR ~ 2 minutes
    - Chiara (4 years old) ~ 4 sec
- Energy
  - 2 car battery → 2~3 hours autonomous operation
- 24/7
  - Interaction
  - Learning
  - …
- Adaptivity
  - To new kitchens
  - ….



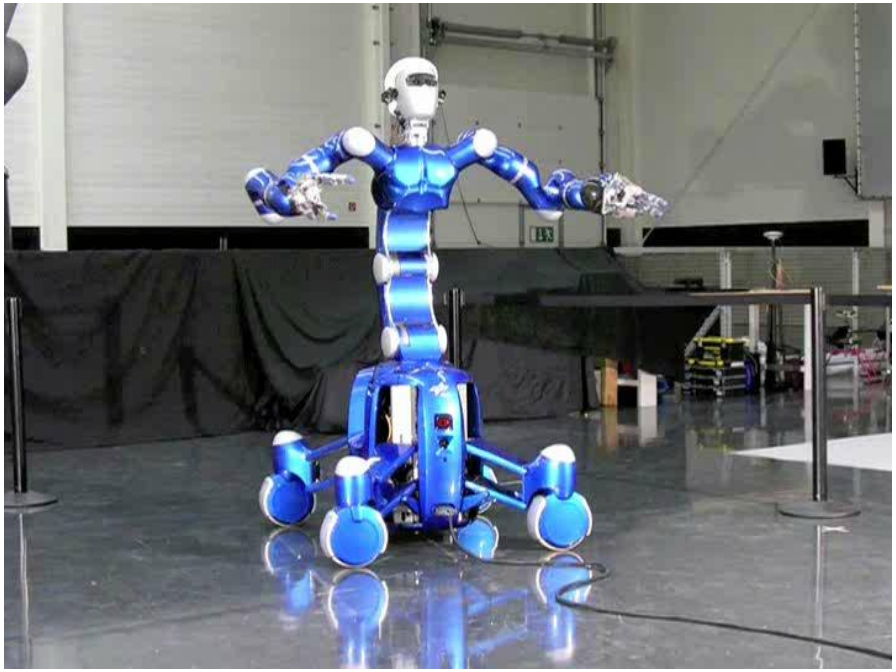
The “X”

- It is NOT the “X” in Self-X
- It is NOT the “X” in Co-X
- It is NOT the state variable in dynamical systems

- It is the value by which we have to speed up robot movies to make robots behave/move in a human-like way.
  - Almost > 1

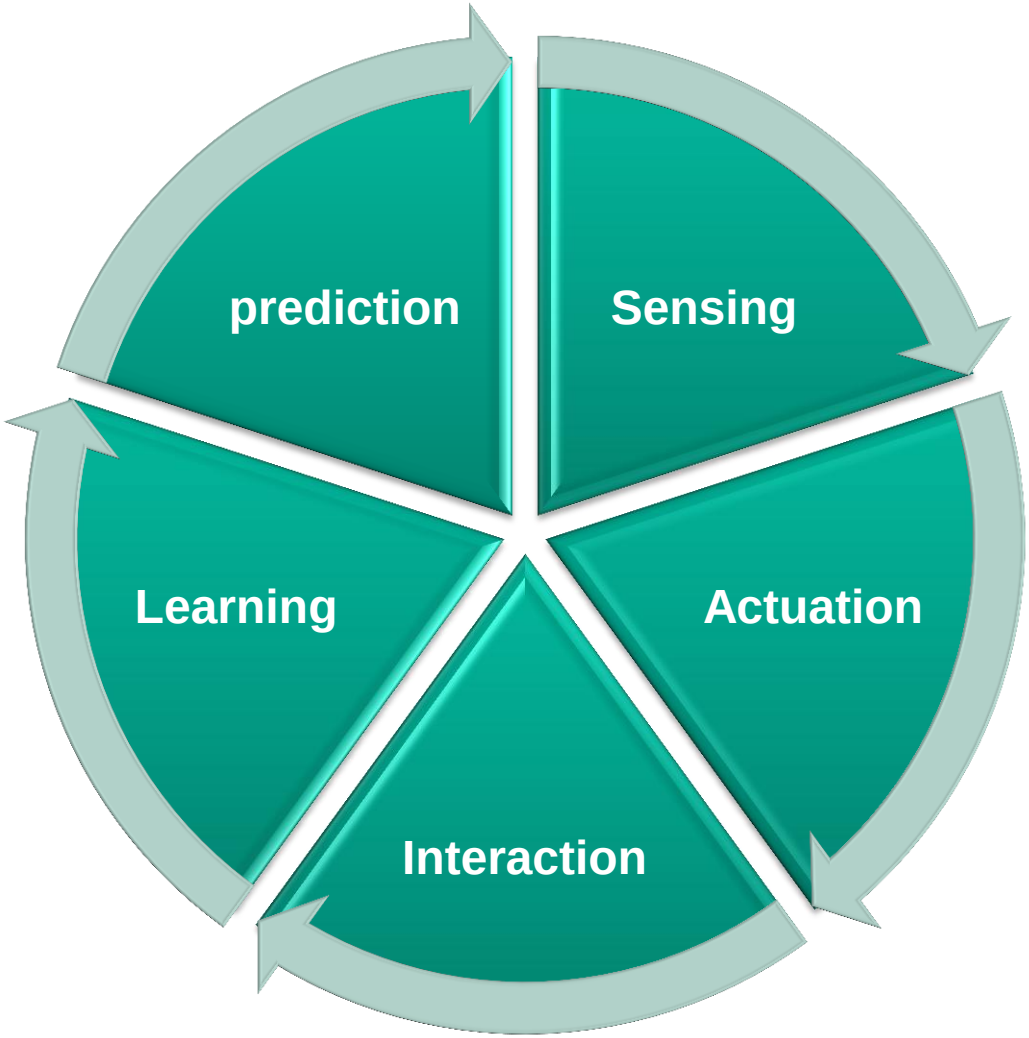
Some counterexamples

- Slowdown instead of speedup videos ☺ (X < 1)



… we need high-performant systems in

Integrated complete humanoid robot systems able to act and interact in 24/7 manner in human-centered environments and to perform a wide variety of tasks



Examples for research challenges

- 24/7 high-performance humanoid robot that is trusted by all citizens in daily life

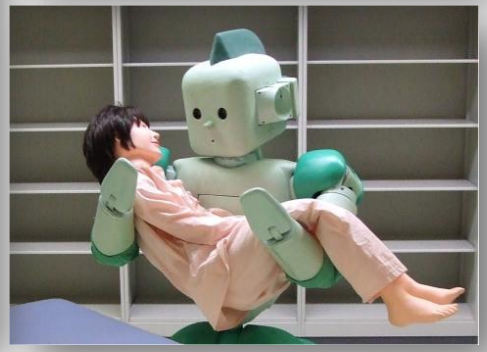
- High-performance humanoid robot that can play tennis

24/7 high-performance humanoid robot: challenges

- Understanding and interpretation
  - Scenes, contexts and situations
- Object categorization
  - Daily objects
- Grasping any object
  - Pin, book, …, beer box
- Navigation in every environment
  - Home, street, super market
- …

24/7 high-performance humanoid robot: challenges

- Human-Robot interaction
  - Multimodal interaction
  - Physical interaction
  - Natural communication
  - Action and activity and intention recognition
  - Human tracking, gesture detection, face detection and identification, emotion recognition
- Social interaction
  - Humor, trust, privacy
- Personalization
  - Adapt to human's needs and habits



24/7 humanoid robot: What to measure?

- Energy consumption
  - Similar to other household appliances (oven, fridge, dishwasher, …)
- Program complexity
  - FLOPs, Memory requirements
- Performance
  - 2015: set/clean the table, load the dish washer or the washing machine, prepare food
  - 2030: Clean the apartment, go shopping (in super market, shopping center, Italian shop, …)
  - 2049: Similar to human caregiver in performance and social interaction
- Price:
  - Cheap car

Humanoid robot that can play tennis: challenges

Humanoid robot that can play tennis: challenges

- **It is not about Tennis!**
- Understanding the body dynamics
- Body balancing and motor coordination
- Safe falling and recovery
- Real-time prediction:
  - Reaction based only on vision would be too late
  - "Sense – Plan – Act" would not work
  - Instead: "Predict – Act – Sense"

Humanoid robot that can play tennis: challenges

- **It is not about Tennis!**
- Multisensory integration (vision, vestibular, haptics, ..)
- Learning
  - of other's behavior and adaptation of own behavior based on past experience
  - to predict and adapt from little experience and few examples
- High speed perception and high speed control

Tennis: What to measure?

- Energy consumption
  - Humanoid robot should be able to play a game with the energy equivalent of a “Maultaschen” dish
- Program complexity
  - FLOPs, Memory requirements
- Performance
  - 2020: Perform basic tennis playing
  - 2030: Steadily win against number 500 of the ATP ranking
  - 2049: Steadily win against number one of the ATP ranking
- Price:
  - Cheap car

Applications/Perspectives

- 24/7 systems with human-like performance
  - Assistance and companions in daily life
- Help in man-made and natural disasters
  - New generation of high-performance humanoids for telepresence with varying level of autonomy
- “Tennis” (it is not about tennis)
  - Understanding the body dynamics
- High performance wearable robots
  - Compensation of physical limitations

ARMAR-X

- Humanoid robots with dual function

Autonomous robot

Wearable Humanoid
„Body suit“

ARMAR-X
????

Karlsruhe Institute of Technology

NEW BODIES FOR HUMANOIDS

New Bodies for Humanoids

- Body, mind and brain are inseparably intertwined

- **Morphological Computation (Rolf Pfeifer)**
  - Integrating morphology and control (“morphological computation”); re-thinking control
  - Materials for sensing and actuation
    - Novel ways for actuation
    - skin (deformable, high-density/ sensitivity, parallel, robust, water proof, re-generating)

Missing technologies

- Hardware
  - Actuation
  - Materials
  - Sensing (skin)
  - Massive connections
  - Computer architectures
- Software
  - Simulators
  - Middleware, standards
  - New computing paradigms

Missing methodologies

- Design principles and quantitative models for the development of systems that
  - explore their own sensorimotor primitives and body morphology
  - explore the environments and the effective interaction with it
  - predict the body dynamics and the physics of the world

- How body morphology allows to cope with
  - morphological change arising through the interaction with the environment
  - tolerance to uncertain variability in performance of robot components

- How reconfigurability and self-reconfigurablility, redundancy, robustness and flexibility can be implemented

Thanks to …

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  - SFB 588 www.sfb588.uni-karlsruhe.de

- European Commission
  - Xperience www.xperience.org
  - PACO-PLUS www.paco-plus.org
  - GRASP www.grasp-project.eu

Thanks for your attention